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IS : 3842 (Part XII) - 1976

*Indian Standard*  
APPLICATION GUIDE FOR  
ELECTRICAL RELAYS FOR AC SYSTEMS  
PART XII DIFFERENTIAL RELAYS FOR TRANSFORMERS

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**BUREAU OF INDIAN STANDARDS**  
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG  
NEW DELHI 110002

# Indian Standard

## APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR AC SYSTEMS

### PART XII DIFFERENTIAL RELAYS FOR TRANSFORMERS

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# *Indian Standard*

## APPLICATION GUIDE FOR ELECTRICAL RELAYS FOR AC SYSTEMS

### PART XII DIFFERENTIAL RELAYS FOR TRANSFORMERS

#### 0. FOREWORD

**0.1** This Indian Standard (Part XII) was adopted by the Indian Standards Institution on 28 June 1976, after the draft finalized by the Relays Sectional Committee had been approved by the Electrotechnical Division Council.

**0.2** Modern power systems are designed to provide uninterrupted electrical supply, yet the possibility of failure cannot be ruled out. The protective relays stand watch and in the event of failures, short-circuits or abnormal operating conditions help de-energize the unhealthy section of the power system and restrain interference with the remainder of it and thus limit damage to equipment and ensure safety of personnel. They are also used to indicate the type and location of failure so as to assess the effectiveness of the protective schemes.

**0.3** The features which the protective relays should possess are :

- a) Reliability, that is, to ensure correct action even after long periods of inactivity and also to offer repeated operations under severe conditions;
- b) Selectivity, that is, to ensure that only the unhealthy part of the system is disconnected;
- c) Sensitivity, that is, detection of short-circuit or abnormal operating conditions;
- d) Speed to prevent or minimize damage and risk of instability of rotating plant; and
- e) Stability, that is, the ability to operate only under those conditions that call for its operation and to remain either passive or biased against operation under all other conditions.

**0.4** The differential relay, besides being used for protection of transformers, is also used for generator protection, feeder protection, etc. This guide covers relays for differential protection of transformers.

**0.5** In the preparation of this guide, considerable assistance has been derived from several published books and from manufacturers' trade literature.

**0.6** This guide has been prepared to assist in the application rather than to specify the relay to be used. This guide deals only with principle of

## **IS : 3842 (Part XII) - 1976**

application of differential relay and does not deal with selection of any particular protective scheme.

**0.7** This guide is one of the series of application guides for electrical relays for ac systems. The other guides in this series are :

- IS : 3638-1966 Application guide for gas-operated relays
  - IS : 3842 (Part I)-1967 Application guide for electrical relays for ac systems : Part I Overcurrent relays for feeders and transformers
  - IS : 3842 (Part II)-1966 Application guide for electrical relays for ac systems : Part II Overcurrent relays for generators and motors
  - IS : 3842 (Part III)-1966 Application guide for electrical relays for ac systems : Part III Phase unbalance relays including negative phase sequence relays
  - IS : 3842 (Part IV)-1966 Application guide for electrical relays for ac systems : Part IV Thermal relays
  - IS : 3842 (Part V)-1968 Application guide for electrical relays for ac systems : Part V Distance protection relays
  - IS : 3842 (Part VI)-1972 Application guide for electrical relays for ac systems : Part VI Power relays
  - IS : 3842 (Part VII)-1972 Application guide for electrical relays for ac systems : Part VII Frequency relays
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## **1. SCOPE**

**1.1** This guide (Part XII) deals with the application of differential relays for transformers for ac systems, covered by IS : 3231-1965\*. It also applies to differential protection of auto-transformers and generator transformer unit.

**1.2** This guide does not cover the principle of system design and system protection.

## **2. TERMINOLOGY**

**2.1** For the purpose of this guide the definition given in IS : 1885 (Part IX)-1966† and IS : 1885 (Part X)-1968‡ shall apply.

## **3. BASIC PRINCIPLE**

**3.1** The basic principle on which a differential relay operates is known as the circulating current principle. It consists in directly comparing the magnitude and phase of the currents entering and leaving the protected section. To accomplish differential protection, current transformers having

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\*Specification for electrical relays for power system protection.

†Electrotechnical vocabulary : Part IX Electrical relays.

‡Electrotechnical vocabulary : Part X Electrical power system protection.

suitable ratios of transformation are interposed in the circuit at both the ends of the protected section. These current transformers have their connected secondaries as shown in Fig. 1A. For simplicity only one phase has been shown. Ideally no current should flow through the differential relay during any condition other than an internal fault condition. That is, if the secondary currents of the two current transformers are designated by  $I_A$  and  $I_B$  and power flow is as shown in Fig. 1A, then current through the relay,  $I_A - I_B$  will be zero.

However, various factors, such as unequal current transformer saturation, magnetizing inrush, etc, make it impossible to achieve such an ideal condition and, therefore, transformer differential relays are provided with different types of restraints described later.

When the fault is within the protected zone and fault current is fed from one end (end A) as shown in Fig. 1B, the current through differential relay will be  $I_A$  and relay will operate. When the fault current is fed from both the ends and the fault is within the protected zone, the current through the relay will be equal to  $I_A + I_B$  and differential relay will operate and this condition is shown in Fig. 1C.

## 4. CHARACTERISTICS

**4.1** A differential relay is characterized by its ability to distinguish between an internal fault requiring isolation of the faulty section and an external fault requiring non-operation of the relay. Therefore, differential relays are so designed that they tend to operate on internal faults and restrain on external faults.

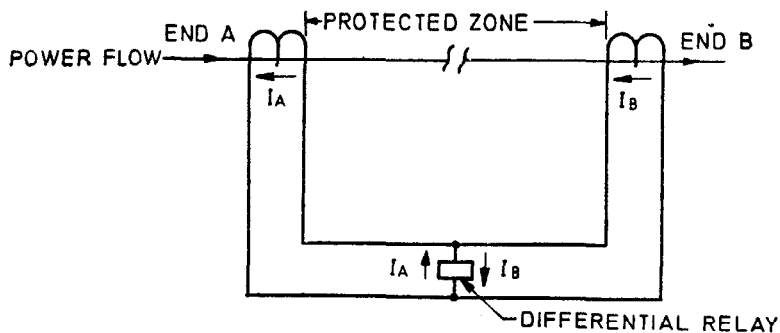
The characteristics of the relay which govern its operating tendency are known as the 'Operating Characteristics' while those which govern its restraining tendency are known as the 'Restraining Characteristics'.

**4.2 Operating Characteristics** — The features which govern the operating characteristics of a differential relay are :

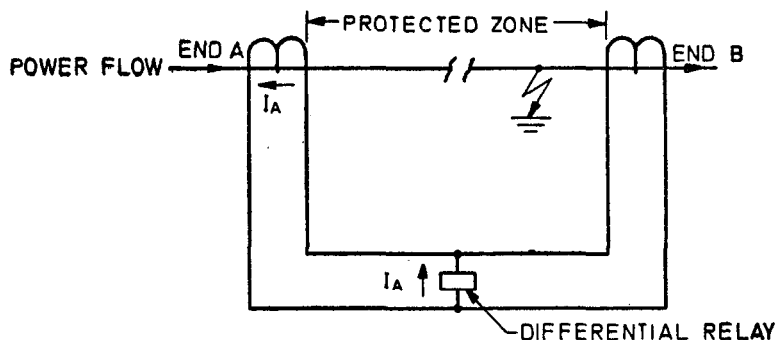
- a) Current setting, and
- b) Operating time.

**4.2.1 Current Setting** — The operating current setting of differential relay determines its sensitivity on internal faults. The normal range of current settings available on differential relays varies from 10 to 100 percent of rated current.

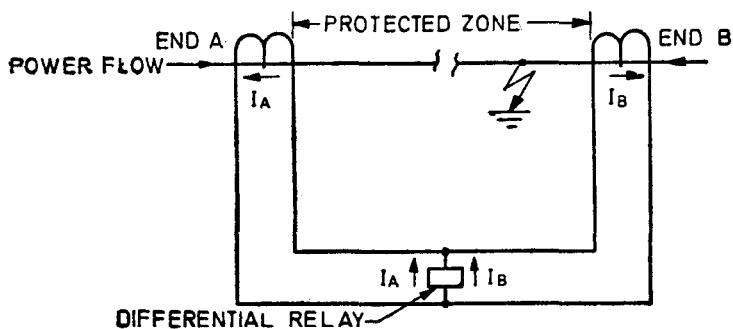
**4.2.2 Operating Time** — The operating time of a differential relay depends on the type of relay (described later) and the magnitude of differential current expressed as a multiple of the current setting. This operating time normally varies from about 25 milliseconds to about 500 milliseconds at twice the current setting, depending upon the type of relay.



Current through relay  $I_R = I_A - I_B$   
 IA No Internal Fault



Current through relay  $I_R = I_A$   
 IB Fault Current Fed from One End



Current through relay  $I_R = I_A + I_B$   
 IC Fault Current Fed from Both Ends

FIG. 1 PRINCIPLE OF DIFFERENTIAL PROTECTION

**4.3 Restraining Characteristics** — In order that the differential relay does not operate during conditions other than genuine internal faults, the following restraining characteristics are necessary :

- a) Stability for external faults,
- b) Stability on magnetizing inrush, and
- c) Stability during over-excitation inrush.

**4.3.1 Stability for External Faults** — A differential relay may maloperate for external faults due to the following :

- a) Current transformer saturation, and
- b) Current transformer mismatch.

**4.3.1.1** Ideally, current transformers on both sides of the protected section should not saturate for external faults. However, if current transformers on one side saturate it will cause spill current to flow through the relay resulting in its maloperation.

**4.3.1.2** Similarly, current transformer ratios on both sides of the protected section should be perfectly matched. However, this may not be possible in all cases. Also, the tap change range provided on the protected transformer will automatically result in current transformer mismatch. While this mismatch may not cause operation of the relay under normal load conditions, it may result in relay operation for external faults.

**4.3.1.3** To ensure that the differential relay remains stable for the above conditions, it is normally provided with a 'bias' feature. This feature is usually expressed in terms of 'percentage bias' and is defined as

$$\frac{\text{Differential current} \times 100}{\text{Through current}}$$

Bias settings normally provided in differential relays vary from 15 to 50 percent. However, self-biasing differential relays are also available in which the bias is automatically adjusted to the current setting.

**4.3.2 Stability on Magnetizing Inrush** — When a transformer primary is switched on to the supply source while the secondary is kept open, a transient magnetizing inrush current flows only on the primary side which appears as an internal fault to the differentially connected relays. As modern transformers are built from cold-rolled steel having a substantially lower hysteresis loss (for they permit operation at high flux densities thus reducing the size of the units) this magnetizing inrush current can approach the short circuit levels, that is, 10 to 12 times the full load current with fairly long time constants of up to 60 seconds. The time constants for inrush current may vary from 10 cycles for very small units to 1 minute for large units. The maximum inrush current occurs if the transformer is energized when the voltage wave is at zero (see Fig. 2). The magnitude and duration of the magnetizing inrush current depends on following factors :

- a) Size of the transformer bank;
- b) Size of the power system;

- c) Resistance and inductance of the system from source to bank;
- d) Type of iron used in the transformer;
- e) Previous history of the bank;
- f) How the bank is energized (residual flux, initial recovery of sympathetic wave); and
- g) Instant of switching.

The effect of source inductance is to reduce the magnitude of inrush current through reducing the magnitude of the excitation voltage. The time constant for the decaying inrush current is a function of the total resistance of the source plus the transformer winding. Hence, transformers near the generating source will have a long inrush. At substations remote from the generating sources, the inrush is not so severe as the inductance and resistance of the line reduce the peak magnitude and quickly damp the current.

A typical magnetizing inrush current wave is shown in Fig. 2.

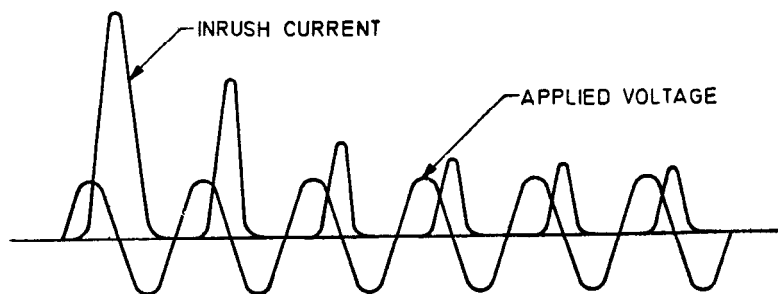


FIG. 2 A TYPICAL MAGNETIZING INRUSH CURRENT WAVE

In order to ensure that the relays do not maloperate due to magnetizing inrush currents, they are either provided with harmonic restraint feature or an inherent time delay feature. These features are described in detail in later clauses.

**4.3.3 Stability During Over-Excitation Inrush**— With the advent of cold-rolled grain-oriented steel in transformer manufacture, modern power transformers are designed to operate at about 90 percent of the saturation flux levels at rated voltages. Therefore, during abnormal system conditions, short-duration over-voltage conditions can occur, resulting in the saturation of the transformer cores. This can cause increase in the excitation current of the transformer of the order of 10 to 100 times the normal value for a voltage rise of 20 to 30 percent. This condition will appear as an internal fault to the differentially connected relay.

In order to ensure that the relays do not maloperate during above conditions some relays are provided with higher harmonic restraint features.

NOTE — This phenomenon can be detected by  $V/f$  (voltage/frequency) relay.

## 5. TYPE OF DIFFERENTIAL RELAYS

**5.0** For the differential protection of power transformers, the following types of relays are normally used, depending upon the rating and the importance of the transformer :

- Unbiased inverse definite minimum time (IDMT) relay (induction type),
- Percentage bias differential relay (induction type),
- High speed differential relay with harmonic restraint feature, and
- High impedance type differential relay (for auto-transformers only).

**5.1 Unbiased IDMT Relay (Induction Type)** — When a power transformer is not equipped with tap-change equipment and the current transformers on each winding are properly matched electrically and magnetically, an unbiased relay may be used as shown in Fig. 3.

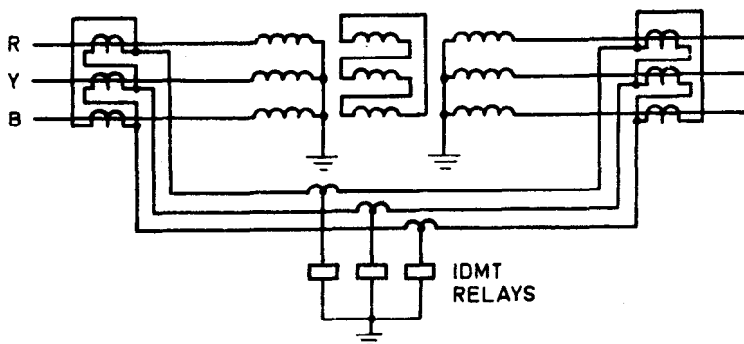


FIG. 3 TRANSFORMER UNBIASED DIFFERENTIAL PROTECTION WITH INDUCTION TYPE IDMT RELAYS

The main disadvantages of this scheme are the need to adopt a high current setting due to current transformer mismatch and the longer duration of fault clearance. Further, the relay may maloperate under external fault condition when a small unbalance under normal condition will be multiplied to a great extent on through faults.

This type of relay can generally be used for transformers rated up to 2 MVA.

**5.2 Percentage Bias Differential Relay (Induction Type)** — This type of relay has bias windings to provide stability on external faults, and an inherent time delay to overcome magnetizing inrush currents. A typical connection of such a relay is shown in Fig. 4.

The percentage bias settings provided in these relays normally vary from 20 to 40 percent. A typical bias characteristic is shown in Fig. 5.

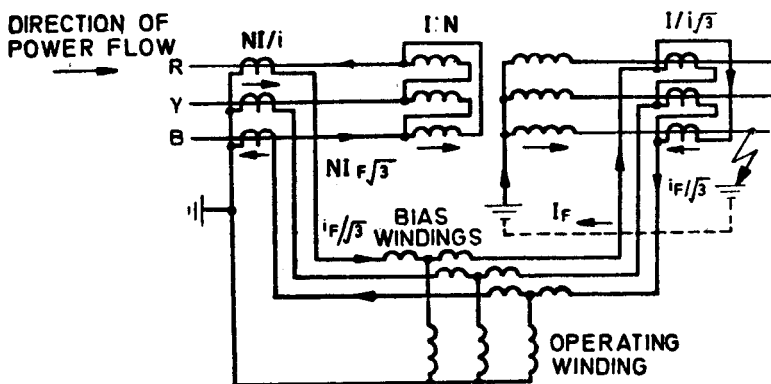


FIG. 4 TYPICAL CONNECTION OF PERCENTAGE BIAS DIFFERENTIAL RELAY (INDUCTION TYPE)

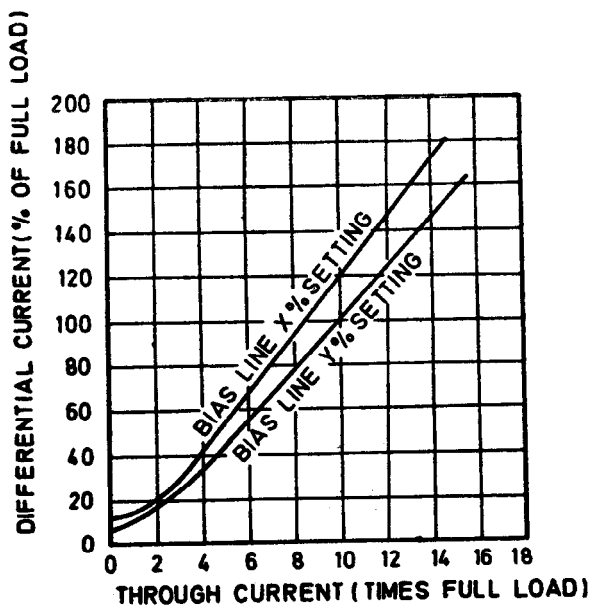


FIG. 5 TYPICAL OPERATING CHARACTERISTICS OF PERCENTAGE BIAS DIFFERENTIAL RELAY

The operating current settings provided in these relays normally vary from 40 to 100 percent. The operating time is usually adjustable from 0.1 to 0.3 seconds at 5 times the current setting to overcome the inrush phenomenon. A disadvantage of this type of relay is its long operating time on internal faults.

This type of relay can be used for transformers rated up to 15 MVA.

**5.2.1** In order to obtain the lowest possible operation time on internal faults without losing stability on magnetizing inrush, the following additional devices can be used with percentage bias differential relays of induction type :

- a) Voltage blocking relay which isolates the tripping circuit of differential relay during charging of transformer, and
- b) Time delay relay having delay on reset which isolates the tripping circuit of differential relay during charging of transformer.

The disadvantage of the above two schemes is that the transformer fault if any, present at the time of charging of the transformer can be detected only after the blocking feature in the tripping circuit of the differential relay is removed.

**5.3 High Speed Differential Relay with Harmonic Restraint Feature** — To achieve high speed operation on internal faults without sacrificing stability on magnetizing inrush, harmonic restraint feature is incorporated in differential relay. This feature is based on the fact that second harmonic component predominates in the magnetizing inrush currents of a transformer, and is negligible in fault currents. The differential relay filters out the second harmonic component and uses it for restraining its operation. The basic principle of this type of relay is shown by a block diagram in Fig. 6.

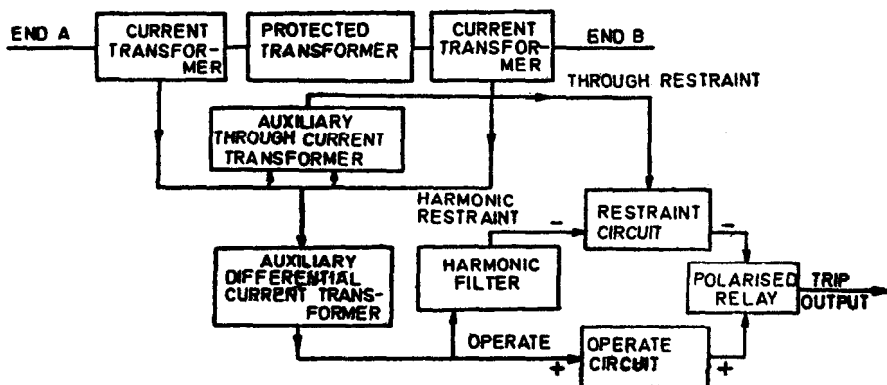


FIG. 6 BASIC PRINCIPLE OF DIFFERENTIAL RELAY WITH HARMONIC RESTRAINT FEATURE

This type of relay is also provided with percentage bias for stability on external faults. The normal bias settings vary from 15 to 50 percent. The operating time of this type of relay is usually less than 40 milliseconds at twice the current setting. The operating current setting generally varies from 10 to 50 percent.

**5.3.1** These relays are also provided with highest instantaneous over-current units to take care of very heavy internal faults. The overcurrent units have a fixed setting of above 8 times the rated current.

**5.3.2** High speed differential relays with harmonic restraint feature are generally recommended for all transformers rated above 15 MVA.

**5.4 High Impedance Type Differential Relay (for Auto-transformers Only)** — While harmonic restraint differential relays can be used for the protection of auto-transformers, high impedance type differential relays offer a simpler alternative. This protection scheme is shown in Fig. 7 from which it will be seen that three sets of current transformers are required, namely, one set on the high voltage side, one set on the low voltage side and one set in the neutral end of the winding. All the current transformers should have the same ratio and rating in order to achieve stability on external faults and magnetizing inrush.

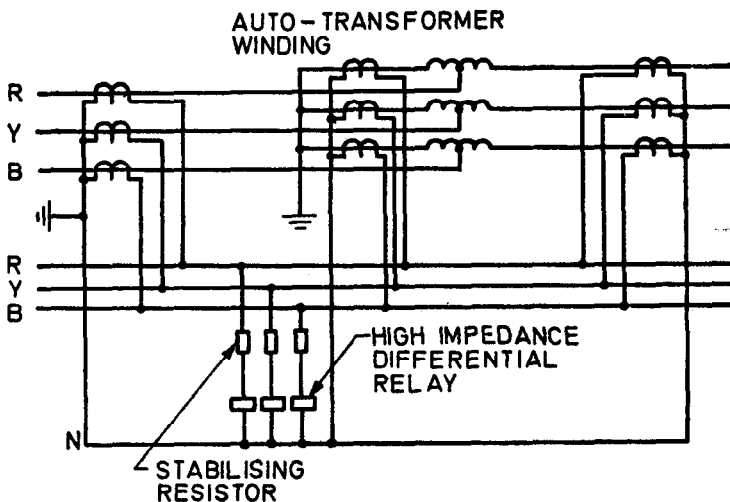


FIG. 7 OVERALL DIFFERENTIAL PROTECTION OF AN AUTO-TRANSFORMER

**5.4.1** The high impedance scheme offers the following advantages over biased and harmonic restraint differential relays :

- a) Higher sensitivity which results in greater percentage of winding being protected, and
- b) Faster operating times on internal faults due to absence of bias windings.

**5.4.2** The high impedance scheme can be used only when the delta tertiary windings of auto-transformers are used as stabilizing windings without being loaded. In case the tertiary windings are to be loaded, harmonic restraint differential relays suitable for 3-winding transformers will have to be used.

NOTE — One corner of the unloaded tertiary delta winding is generally earthed via the transformer neutral so that the tertiary winding is covered in the transformer differential zone.

## 6. CONNECTIONS OF DIFFERENTIAL RELAYS

**6.1** The circulating current system as applied to a power transformer is fundamentally the same as that for machines, with the exception that there is often a phase angle difference and always a magnitude difference between the currents entering and leaving the transformers.

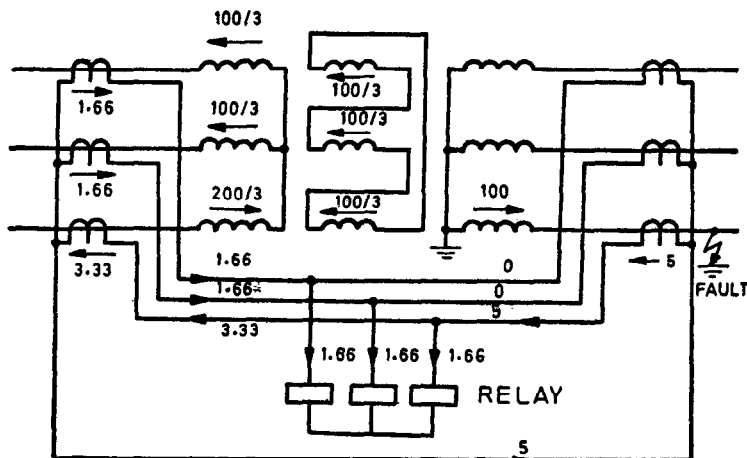
The difference in magnitude of currents is taken care of in the differential relay by choosing suitable current transformer ratios. When this is not possible, auxiliary current transformers of suitable ratios are used.

The difference in phase angles of currents is taken care of by proper connection of current transformers so as to obtain identical phase shift in the current transformer secondary circuits, for example, in delta/star power transformers, the current transformers on the delta side are connected in star and the current transformer on the star side are connected in delta; in the case of star/delta transformers, the current transformer connections adopted are *vice versa*.

Delta connections on the star winding of a solidly grounded transformer are employed to filter out zero-sequence currents so that they do not flow into the pilots across which differential relay is connected. This is done to avoid maloperation of the relays in the event of a fault to ground on the star-winding of the transformer when the location of fault is external to the protective zone.

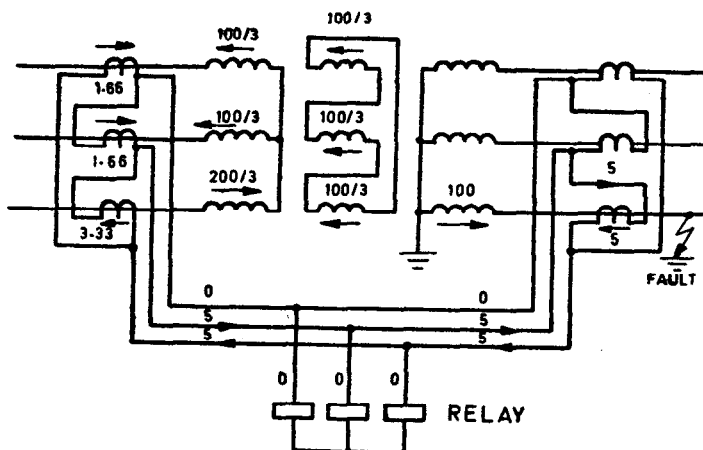
**6.2** In the case of star/star power transformers, since no phase angle difference is introduced, it would appear logical to connect the current transformers on both sides in star as shown in Fig. 8. However, this connection results in maloperation of the differential relay on external phase to earth faults because of the zero-sequence unbalance in the relay. Therefore, it is necessary to connect the current transformers on both sides in delta as shown in Fig. 9. The delta connected current transformers filter out the zero-sequence component of fault currents in the relay circuit and ensure stability on all types of external faults.

6.3 In unit type of systems, when a power transformer is directly connected to a generator without an intervening circuit-breaker, both the generator and the transformer are protected by means of an overall differential scheme using biased harmonic restraint differential relays, as shown in Fig. 10.



Circulating current system for star/star power transformer

FIG. 8 CURRENT TRANSFORMERS STAR CONNECTED GIVING INSTABILITY ON THROUGH EARTH FAULT



Circulating current system for star/star power transformer

FIG. 9 CURRENT TRANSFORMERS DELTA CONNECTED GIVING STABILITY ON THROUGH EARTH FAULTS

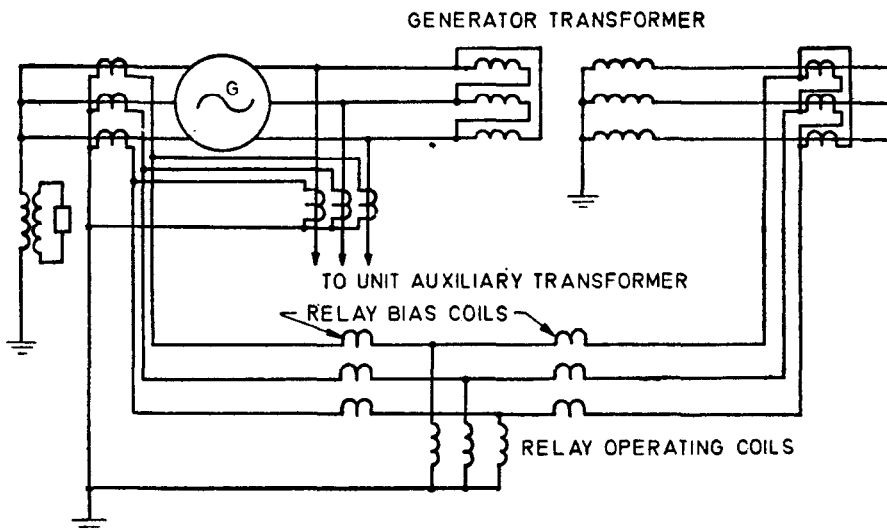


FIG. 10 ARRANGEMENT OF GENERATOR TRANSFORMER OVERALL BIASED DIFFERENTIAL PROTECTION

## 7. CHECKING OF CONNECTIONS FOR DIFFERENTIAL RELAYS

**7.1** On a star-delta bank, the current transformers on the star side are connected in delta and the current transformers on delta side are connected in star. This is done for correct phasing and to eliminate zero-sequence current from operating the differential relays when the star is grounded. If the star is ungrounded, then opposite connections could be used, but these are not conventional.

The connections of the differential relays are important. They must be correct. These may be made or checked in two stages, namely, (a) phasing, and (b) ratio. A work sheet for connecting differential relays around a two-winding bank is given in Fig. 11.

**7.2 Phasing Check — Two Winding Bank** — Starting on the star side of the power bank, assuming that currents  $I_a$ ,  $I_b$  and  $I_c$  are flowing through the bank to an external 3-phase fault or load, trace the currents through the delta to the delta side phase wires, then through the star-connected current transformers to the relay. This determines what current should flow in the star side restraint coil, and enables the star side current transformers to be connected in delta properly for correct phasing under all conditions.

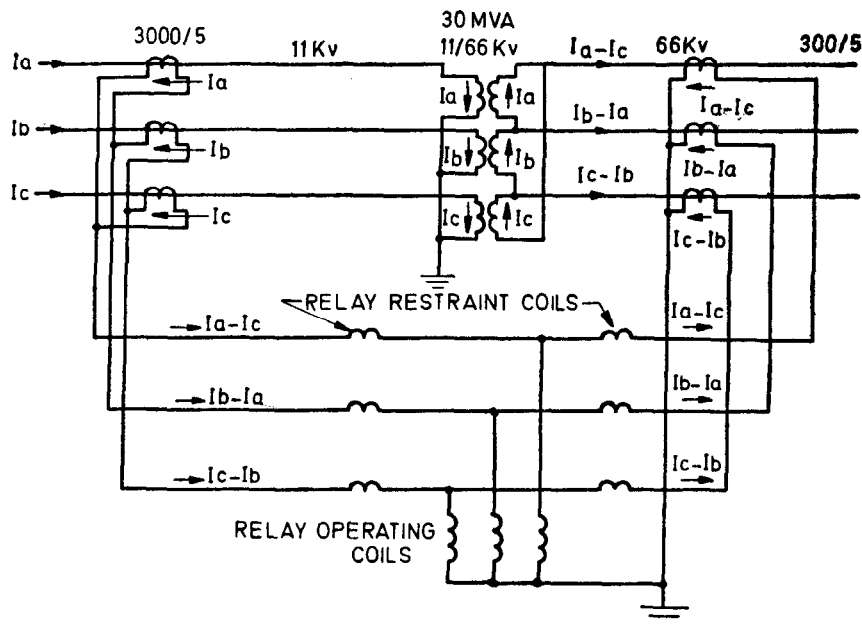


FIG. 11 COMPLETE PHASING AND RATIO CHECK AROUND TWO-WINDING TRANSFORMER BANK

### 7.3 Ratio Check — Two-Winding Bank

*Assumptions:* Transformer particulars = 30 MVA; 11/66 kV, star/delta (see Fig. 11)

*Current Transformer Ratio*

11 kV side	3 000/5
66 kV side	300/5

Then, current on the 11 kV side =  $\frac{30\,000 \times 10^3}{\sqrt{3} \times 11 \times 10^3} = 1\,575 \text{ A}$

Current on the 66 kV side =  $\frac{30\,000 \times 10^3}{\sqrt{3} \times 66 \times 10^3} = 262.5 \text{ A}$

Equivalent current transformer secondary pilot currents are :

11 kV side =  $\frac{1\,575}{3\,000} \times 5 \times \sqrt{3} = 4.55 \text{ A}$

66 kV side =  $\frac{262.5}{300} \times 5 = 4.38 \text{ A}$

Thus, the difference current of 0.17 A flows through the operating winding. The percentage unbalance is  $\frac{0.17}{4.38} = 3.88$  percent which is permissible.

**7.4 Phasing Check — Three-Winding Bank** — The same procedure of phasing and ratio check is used for three-winding transformers. For the phasing checks, assume one side of the transformer is the primary and the other two windings are secondaries to determine the correct direction and phase of the restraint currents. For ratio checks, it is important to check any two windings as if the bank were two winding unit and with no current in the third. Then check any other pair in the same manner, so that all ratios are correct for any distribution of fault or load current.

A work sheet for connecting differential relay around three-winding transformer bank is shown in Fig. 12.

### 7.5 Ratio Check — Three-Winding Bank

*Assumptions:* Transformer particulars = 75 MVA, 132/33/11 kV star/star/delta (see Fig. 12)

*Current Transformer Ratio*

Primary : 132 kV	750/1
Secondary : 33 kV	3 000/1
Tertiary : 11 kV	5 000/1

$$\text{Then, Primary current} = \frac{75 \times 10^6}{\sqrt{3} \times 132 \times 10^3} = 328 \text{ A}$$

$$\text{Secondary current} = \frac{75 \times 10^6}{\sqrt{3} \times 33 \times 10^3} = 1\,310 \text{ A}$$

$$\text{Tertiary current} = \frac{75 \times 10^6}{\sqrt{3} \times 11 \times 10^3} = 3\,930 \text{ A}$$

Equivalent current transformer secondary pilot currents are :

$$\text{Primary} = \frac{328 \times \sqrt{3}}{750} = 0.756 \text{ A}$$

$$\text{Secondary} = \frac{1\,310 \times \sqrt{3}}{3\,000} = 0.756 \text{ A}$$

$$\text{Tertiary} = \frac{3\,930}{5\,000} = 0.786 \text{ A}$$

Now, to demonstrate that balance is correct for any distribution of current, assume 50 MVA going out of 33 kV winding and 25 MVA going out of 11 kV winding. Under these conditions:

*132 kV Side, 75 000 kVA in*

$$\text{I Primary} = 328 \text{ A}$$

$$\text{I Secondary} = \frac{328}{750} \times 1 = 0.437 \text{ A}$$

$$\text{I Relay} = 0.437 \times \sqrt{3} = 0.756 \text{ A}$$

*33 kV Side, 50 000 kVA Out*

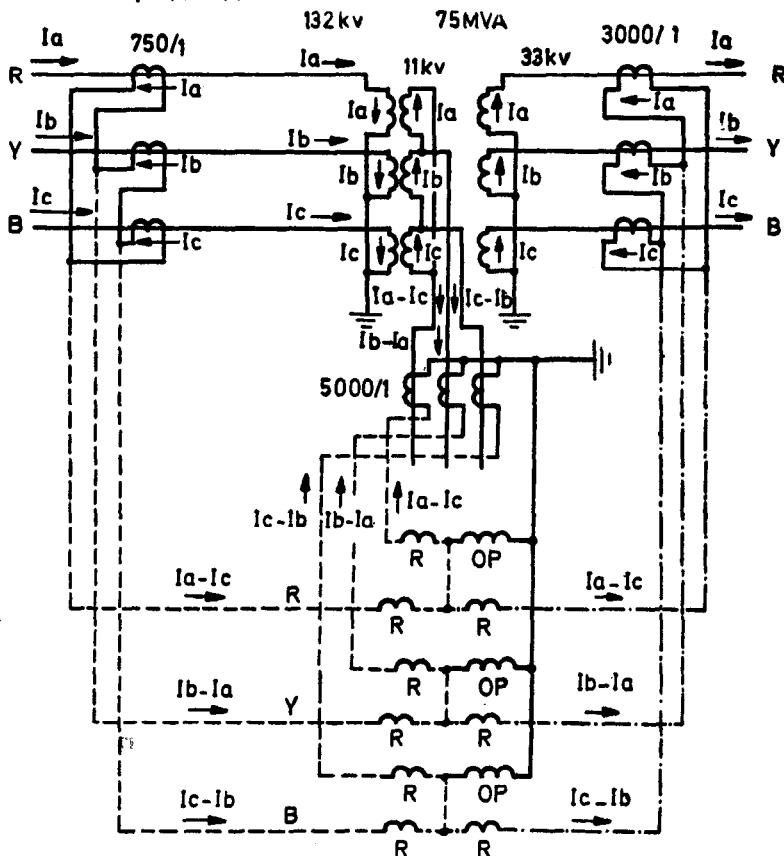
$$\text{I Primary} = \frac{50\,000 \times 10^3}{\sqrt{3} \times 33 \times 10^3} = 875 \text{ A}$$

$$I_{\text{Secondary}} = \frac{875 \times 1}{3000} = 0.292 \text{ A}$$

$$I_{\text{Relay}} = 0.292 \times \sqrt{3} = 0.506 \text{ A}$$

11 kV Side, 25 000 kVA Out

$$I_{\text{Primary}} = \frac{25000 \times 10^3}{\sqrt{3} \times 11 \times 10^3} = 1310 \text{ A}$$



OP = relay operating coils.

R = relay restraint coils.

NOTE — The dotted lines show the connections for a phasing check between the 132 and 11 kV windings assuming the 33 kV circuit does not exist. The dash lines show the connections for a phasing check between the previous connections made for the 132 kV side and the 33 kV winding assuming that the 11 kV circuit does not exist. With this method phasing is correct for any distribution of currents through the three windings.

FIG. 12 COMPLETE PHASING AND RATIO CHECK AROUND THREE-WINDING TRANSFORMER BANK

$$I_{\text{Secondary}} = \frac{1\,310 \times 1}{5\,000} = 0.262 \text{ A}$$

$$I_{\text{Relay}} = 0.262 \text{ A}$$

Thus, the check is correct as  $0.756 \text{ A}$  balance  $0.506 + 0.262 = 0.768 \text{ A}$  very closely.

NOTE — Where the current transformer ratios do not match interposing current transformers or auxiliary balancing auto-transformers are required to balance the relay current.

## 8. AMOUNT OF WINDING PROTECTED AGAINST EARTH FAULTS

**8.1** The amount of winding that can be protected by a differential system is dependent on the method of system earthing. With solidly earthed systems practically there is no problem in obtaining the desired protection coverage since the fault current is only limited by the position and configuration of the faulted portion of the winding. With a resistance earthed neutral the fault current is limited by the resistor and furthermore, since the arrangement of current transformers eliminate the zero-sequence component of the fault current, the combined effect desensitises the differential protection. The amount of winding that can be protected for a given setting and neutral earthing resistor values is shown in Fig. 13. The primary operating value of the relay is expressed as percentage of the current rating of the resistor.

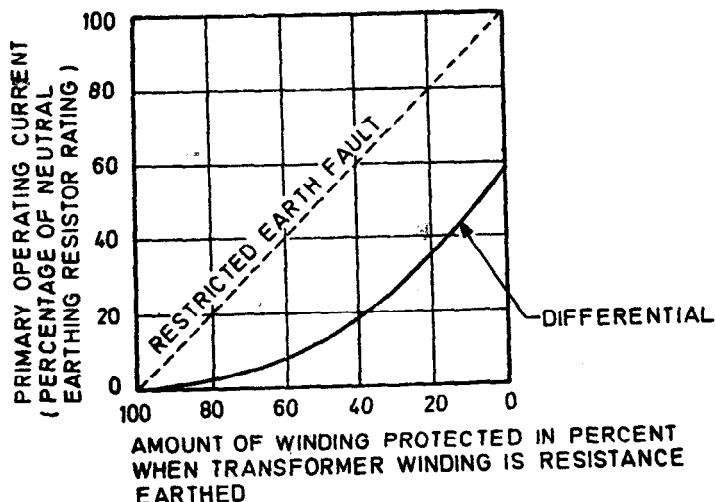


FIG. 13 AMOUNT OF WINDING PROTECTED AGAINST EARTH FAULTS

## 9. CURRENT TRANSFORMER REQUIREMENTS FOR DIFFERENTIAL PROTECTION

9.1 Figure 14 shows the dependence of secondary current upon the primary current of the current transformers and it is clear that characteristics of current transformers  $CT_1$  and  $CT_2$  do not match and as a result of which there always flows a current of unbalance through the relay and this unbalance current increases as the primary current increases. The worst condition for a transformer differential relay is reached when current transformers on one side of the transformer get saturated due to heavy through fault conditions. So the current transformers to be used for the differential protection should be so selected that their operation should take place on unsaturated portion of their characteristics. Further to have a lower unbalance current, specially matched current transformers having similar characteristics should be used.

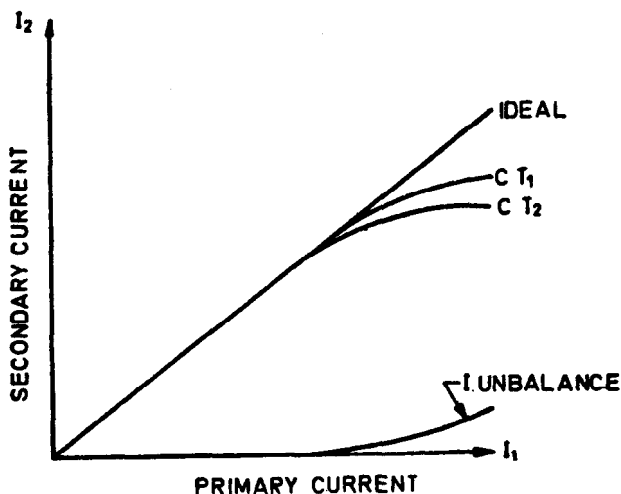


FIG. 14 RELATION BETWEEN PRIMARY AND SECONDARY CURRENT OF CURRENT TRANSFORMER

A differential current transformer must be capable of producing a minimum knee point voltage. The knee point voltage may be calculated as follows :

*For Induction Disc Type Relay*

a)  $V_K = 2I_t (R_{CT} + R_L + R_R)$  for star-connected current transformers.

b)  $V_K = \frac{2I_t}{\sqrt{3}} [R_{CT} + 3(R_L + R_R)]$  for delta-connected current transformers.

*For High Speed Differential Relays*

$V_K = K I_t (R_{CT} + 2R_L + R_R)$  for both star- and delta-connected current transformers.

where

$K$  = a constant to be provided by the manufacturer and which is dependent on  $X/R$  ratio of the system,

$R_R$  = relay burden in ohms,

$R_L$  = one way lead resistance between current transformers concerned and relay circuit,

$I_t$  = maximum secondary fault current in amperes, and

$R_{CT}$  = current transformer secondary resistance in ohms at 70°C.

NOTE — The above knee point voltage formulae are typical and for actual application manufacturer should be referred to.

**9.2** The auxiliary current transformers, where used, should be designed to comply with the same criteria as the main current transformer. The requirements of auxiliary current transformers will depend on its location, that is, whether it is mounted near the main current transformer or control panel. The ratio and connections of the auxiliary transformers are so determined that the secondary currents are balanced. The secondary currents of current transformers in power transformers with tap changers should be balanced at the normal ratio of the transformer.

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